PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G01R 19/00, 17/00

A1

(11) International Publication Number: WO 99/42845

(43) International Publication Date: 26 August 1999 (26.08.99)

(21) International Application Number: PCT/AU99/00096

(22) International Filing Date: 19 February 1999 (19.02.99)

(30) Priority Data:
PP 1922 19 February 1998 (19.02.98) AU

(71) Applicant *(for all designated States except US)*: QUEENSLAND UNIVERSITY OF TECHNOLOGY [AU/AU]; 2 George Street, Brisbane, QLD 4000 (AU).

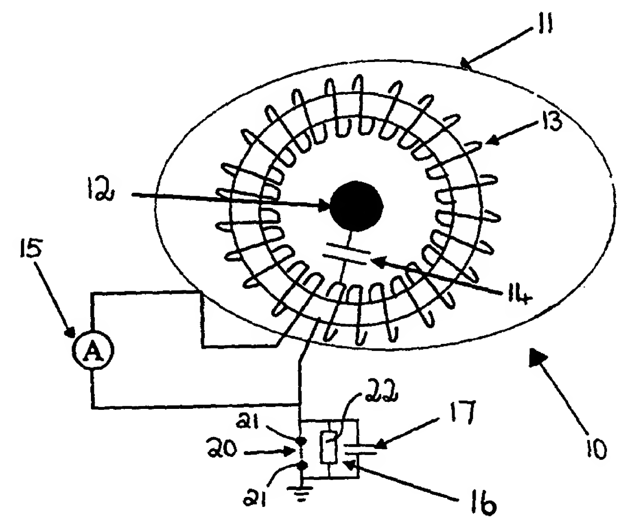
(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: BIRTWHISTLE, David [AU/AU]; 31 Karowara Street, The Gap, QLD 4061 (AU).

(74) Agent: KAPERNICK, Gai, M.; Pizzeys Patent and Trade Mark Attorneys, Trustee House, Level 6, 444 Queen Street, Brisbane, QLD 4000 (AU).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: METHOD AND APPARATUS FOR MONITORING AC CIRCUITS



(57) Abstract

There is provided a method and apparatus for monitoring AC circuits, particularly for monitoring the condition of high voltage circuit breakers. High voltages are measured by connecting an external capacitor (17) between the secondary winding (13) of a current transformer (11) and ground (16), across the removable link (20). This connection, with the link (20) removed, produces a capacitor voltage divider (10) in which the high voltage element of the divider is the stray capacitance (14). The low voltage element of the divider is the external capacitor (17). The voltage on the load and supply side of a circuit breaker is measured using capacitor voltage dividers (10) and the voltage signals are fed to separate inputs on a multi-channel wave-form recording device.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav	TM	Turkmenistan
BF	Burkina Faso	GR	Greece		Republic of Macedonia	TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's	NZ	New Zealand		
CM	Cameroon		Republic of Korea	PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

METHOD AND APPARATUS FOR MONITORING AC CIRCUITS

This invention relates to methods and apparatus for monitoring AC circuits.

This invention has particular but not exclusive application to methods and apparatus for monitoring the condition of high voltage circuit breakers and for illustrative purposes reference will be made to such application. However, it is to be understood that this invention could be used in other applications, such as monitoring and analysis of other electrical switches and contacts, and other circuit elements and conditions.

Substation switchgear may typically include assemblies of three-phase busbars and circuit breakers, current transformers, voltage transformers and associated instrumentation. All equipment is generally contained within metal enclosures. Typically equipment of this type is found in substations of power utilities which have operating voltages in the range 11 kV to 33 kV. Three-phase circuits connect the busbars of the switchgear to the low voltage side of the step-down transformer. Loads are connected to the busbar by other circuits. All outgoing and incoming circuits to the switchgear are usually controlled by a circuit breaker which is part of the switchgear assembly. Circuit breakers may be operated intentionally to switch circuits on and off or may operate automatically to disconnect faults in the electricity network.

Maintenance on circuit breakers has traditionally been carried out at fixed intervals by opening the circuit breaker, racking it out to isolate it from the electricity supply and giving the circuit breaker a complete overhaul. With oil filled circuit breakers the overhaul involves the removal of the old oil, operation of the mechanism - automatically and manually, inspection and, if necessary, replacement of the contacts and refilling with clean oil.

In order to give maintenance crews more information on the condition of circuit breakers a number of diagnostic methods are available. One method is to fit an electrical displacement transducer to the mechanism that will measure displacement of important parts of the mechanism. Displacement is measured during opening and closing of the circuit breaker and resulting traces are compared with traces form pervious circuit breaker operations. Differences in

the traces indicate changes in the operating time of the circuit breaker mechanism.

Another method is to pass high direct current through the de-energised and isolated circuit breaker and to measure the voltage across the circuit breaker as it is opened and closed. The voltage signal measured in this way gives time from trip pulse to contact separation and duration of contact arcing. Instruments that facilitate this measurement are available commercially.

Vibration analysis has been used to record noises emitted by the circuit breaker contacts and mechanism during opening and closing. Proponents of this method claim that information about contact timing can be obtained from analysis of the vibration signatures. However, uncertainty in interpretation of results from this technique appears to have restricted its use.

All currently available techniques in widespread use for monitoring the condition of circuit breakers require that circuit breakers be removed from service prior to diagnostic testing.

There is also pressure on electricity utilities to reduce all costs, including maintenance. Therefore, there is a greater need for simple, inexpensive, non-invasive techniques that will enable the condition of circuit breakers to be checked on line. Such a procedure would enable savings to be made by increasing times between overhauls and by identifying potential failures before they occur.

The present invention aims to alleviate at least one of the foregoing disadvantages and to provide methods and apparatus for monitoring AC circuits which will be reliable and efficient in use.

With the foregoing in view, this invention in one aspect resides broadly in a method of monitoring an AC circuit including the steps of:

providing a current transformer driven by a conductor of said AC circuit;

determining a capacitance between a component of said current transformer and said conductor;

utilizing said capacitance as the high voltage limb of capacitor voltage divider, the low voltage limb including a reference capacitance between the secondary winding of said current transformer and a reference potential, and

monitoring said circuit across said reference capacitance.

In a further aspect this invention resides broadly in apparatus for monitoring an AC circuit and including:

a current transformer driven by a conductor of said AC circuit and having a capacitance between a component of said current transformer and said conductor;

a reference capacitance between the secondary winding of said current transformer and a reference potential, and

signal output terminals across said reference capacitance.

The current transformer may be purpose built or selected from the measurement class transformers and protection transformers currently in use in substation switchgear for the purposes of primary current measurement and fault control respectively. Preferably, the current transformer is of the measurement class to avoid interference with the fault control primary purpose of a protection transformer. Further, during high fault currents the output voltage of the fault current transformers may be several tens of volts. This signal will interfere with the voltage produced by the capacitor voltage transformer formed utilising the current transformer. Measurement current transformers, however, are designed so that magnetic saturation limits the output voltage to no more than a few volts.

The determined capacitance between a component of the current transformer and the conductor may be any capacitance capable of functioning as the high voltage side of a voltage divider. For example, in the case of unshielded current transformers of the conventional substation type, the stray capacitance between the secondary winding of said current transformer and the conductor may be utilized. In most installations, this capacitance is typically in the region of 1nF.

In the case of shielded transformers, these generally comprise a grounded electrostatic shield disposed between the secondary winding and the conductor. In this case the capacitance may be that determined between the grounded electrostatic shield and said conductor, conveniently accessed by tapping in to the grounding wire of the shield.

The reference potential may be any selected potential consistent with the purpose of providing meaningful output across the reference capacitance.

Preferably, the reference potential is ground. In the case of conventional current transformers, these generally have a secondary tap to ground. Accordingly, the reference capacitor may simply be a capacitor interposed in this ground link.

Preferably, in the case of transformers having a further purpose such as current measurement in the secondary winding, the reference capacitance may be shortable by a removable link, the installation of which restores the transformer to its current measuring function. The external nature of this ground link provides an additional advantage of making the reference capacitor external, thus simplifying data acquisition.

In the case of apparatus utilizing the stray capacitance between the primary conductor and the secondary winding as the high voltage limb of the voltage divider, the reference capacitance may be in the region of 0.1μF, giving a voltage divider value of 100:1. Higher ratios are obtained by choosing higher values for the reference capacitance. Capacitor voltage dividers in accordance with the foregoing have been found to have a constant attenuation at frequencies of up to 1 megahertz.

Measurement of the voltage across the reference capacitor in real time provides a faithful reflection of voltage performance of the primary circuit including transient phenomena such as switching, and environmental matters such as insulation performance of metal clad switchgear. Accordingly, it is preferred that the monitoring aspect of the present invention be monitoring of the voltage characteristics in real time across the reference capacitor. Since the transient periods of change in the circuit are short term phenomena, it is preferred that the monitoring function be accompanied by a recording function for analysis against the known parameters of the circuit elements such as circuit breakers.

In the case of circuit breaker performance, useful data may be obtained from both the supply and load sides of the breaker. Accordingly, in a further aspect this invention in one aspect resides broadly in a method of monitoring a circuit breaker including:

providing the load and supply sides of said circuit breaker with monitoring apparatus each including a current transformer driven by respective load and

supply conductors, each having a capacitance between a component of said current transformer and respective said conductors, said capacitance forming the high voltage limb of capacitor voltage divider, the low voltage limb including a reference capacitance between the secondary winding of said current transformer and a reference potential, and

monitoring said circuit breaker across both said reference capacitances.

Either current transformer may be integral part of the switchgear or if necessary, may be suitably introduced into the switchgear.

When current transformers have an electrostatic shield between their secondary windings and the high voltage primary it is not possible to use the secondary winding as a voltage divider. In this case the capacitance between the screen and the high voltage primary of the current transformer can be used as the high voltage limb of a voltage divider provided the ground connection of the sheath is grounded through an accessible link.

The monitoring means may measure across one or more phases switched by the circuit breaker. The voltage may be measured during any period of operation. However, it is preferred that the voltage characteristics at the reference capacitor are measured during the opening and closing operations in a power system. The monitoring means may include recording apparatus.

The recording apparatus may be any suitable instrument that is able to record waveforms such as voltage and current. For example, the recording apparatus may be selected from a digital oscilloscope or a PC-based transient recording systems. The recording apparatus may be multi-channel so that the different type of signals may be fed to separate channels. For example, the voltage signals from the first and second external capacitors may be fed to separate inputs.

Other signals may also be fed to the recording apparatus for analysis. For example, signals derived from the trip and close signals to the said circuit breaker and signals derived from the secondary winding of at least one of the current transformers may be fed to the recording apparatus. A Rogowski-coil-based current measuring device may be used to read the signals from the secondary winding of a current transformer. The current transformer may be

the current transformer of circuit monitoring apparatus as hereinbefore described.

The recording apparatus may be triggered by a trip or a close signal to the circuit breaker, whereby the voltage and current waveforms associated with any opening or closing operation can be recorded.

Analysis of the recorded waveforms allows the inference of many characteristics about the condition of the circuit breaker. It is to be appreciated that a person skilled in the art will be able to infer characteristics about the condition of the circuit breaker from the recorded information, by comparison with the corresponding as-manufactured parameters.

Waveforms across circuit breakers are commonly measured in test stations during circuit breaker type tests and it is accepted practice for experts to use these waveforms to infer may characteristics about the condition of the circuit breakers. Examples of circuit breaker parameters which may be determined in accordance with the methods of the present invention include the time from application of a breaker trip signal to main contact separation, total arcing time on separation of the main contacts, dielectric performance such as the envelope of values of repeated breakdown voltage as a function of time after final 50Hz current interruption, time to current flow from close signal, time to initial contact on close signal, and the integrated total arc energy during opening and closing.

It has also been determined that the output of monitoring apparatus in accordance with the present invention may be useful in determining the insulative performance of metal clad substation switchgear and other like apparatus. Such apparatus is generally maintained with the metal housing insulated from ground at all points except a designated ground link, and the apparatus is protected by frame leakage protection. Repeated transient high frequency waveforms superimposed on the 50 Hz phase voltage waveform and detected using the monitoring apparatus in accordance with the present invention may be indicative of partial discharges across the insulation of the apparatus, and thus be indicative of insulative breakdown prior to a ground leakage fault. Whether or not such high frequency transients are in fact due to partial discharge may be determined by correlation with a signal derived from

the ground linkage, which is the path taken by all inductive and conductive transients in the metal housing.

Accordingly, in a further aspect, this invention resides broadly in a method of determining the condition of the insulation of metal clad switchgear including:

identifying high frequency transient voltage waveforms superimposed on the supply voltage waveform, and

determining any correlation between said transient voltage waveforms and transient high frequency currents measured in the ground connection of the metal cladding.

The identification of high frequency transient voltage waveforms superimposed on the supply voltage waveform is preferably achieved by analysis of the output of monitoring apparatus including a current transformer driven by a conductor, the switchgear having a capacitance between a component of the current transformer and the conductor which is utilized as the high voltage limb of capacitor voltage divider, the low voltage limb including a reference capacitance between the secondary winding of the current transformer and a reference potential, the output being the voltage waveform across the reference capacitance.

The transient current may be measured with any suitable device. Preferably, the currents are measured using a Rogowski coil. It is also preferred the current transformer is a measurement class transformer, rather than a protection transformer.

The presence of simultaneous voltage and current signals gives an indication that discharges are occurring inside the switchgear. The magnitude of the voltage disturbances gives an indication of the severity of the insulation problem.

In order that this invention may be more readily understood and put into practical effect, reference will now be made to the accompanying drawings which illustrate a preferred embodiment of the invention and wherein FIG. 1 illustrates apparatus in accordance with the present invention.

A capacitor voltage divider 10, as illustrated in FIG 1, is integrally formed with a current transformer 11 which in this embodiment drives an ammeter 15.

The current transformer 11 comprises a bar primary 12 about which is located an annular secondary winding assembly 13 in series with the ammeter 15. A stray capacitance represented as a circuit element at 14 exists between the bar primary 12 and the secondary winding 13. Typically, the stray capacitance 14 is about 1nF.

The secondary winding 13 of current transformers are usually connected to ground 16 at one point. In the present embodiment however the connection to ground is interrupted by a removable link 20. Typically, the voltage output of the secondary winding of a current transformer 11 would, with primary load currents equal or less than the normal load current of the circuit breaker, be not more than a few volts.

High voltages in the power system are measured by connecting an external capacitor 17 between the secondary winding 13 of the current transformer 11 and ground 16, across the removable link 20. This connection, with the link 20 removed, produces a capacitor voltage divider 10 in which the high voltage element of the divider is the stray capacitance 14. The low voltage element of the divider is the external capacitor 17 which in the present embodiment is chosen to have a value of about 0.1mF, giving a voltage divider ratio of about 100:1. The capacitor voltage divider 10 so produced has a constant attenuation at frequencies of up to 1 megahertz. The output signal is fed into an analysing instrument of choice such as an oscilloscope or PC at terminals 21. The apparatus is protected by surge protector 22.

This embodiment comprises a new technique for assessing the condition of high voltage circuit breakers in service. The basis of the method involves measurement of the voltage across one or all three poles of the circuit breaker during opening or closing operations in the power system. The voltage on either side of the circuit breaker is measured using voltage divider current transformers that are usually an integral part of the switchgear.

The voltage measured across the external capacitor 17 gives a direct measure of the voltage from the high voltage conductor to ground. Two current-transformer voltage dividers 10 of the type shown in Figure 1 are used to measure the voltage across a circuit breaker. One current transformer is chosen to be on the load side of the circuit breaker and the other transformer is

chosen to remain connected to the supply when the circuit breaker under investigation operates. Voltage signals from both voltage dividers are fed to separate inputs on a multi-channel, waveform-recording device such as a digital oscilloscope or PC-based transient recording system. Signals derived from the trip and close signals to the circuit breaker under investigation are also fed to separate channels of the waveform recorder, as is a signal which is derived form the secondary winding of one of the current transformers, using a standard clip-on Rogowski-coil-based current measuring device. The waveform-recording instrument may be triggered either by a trip or a close signal to the circuit breaker under investigation and the transient voltage and current waveforms associated with any opening or closing operation recorded.

The present method is simpler and gives more information than any previously available diagnostic method. It enables timing measurements to be obtained with actual current flowing in the circuit breaker which is important as electromagnetic forces produced by the current in the circuit breaker may affect the operating time of the circuit breaker.

Programming of the PC-based data acquisition system enables the above characteristics to be extracted automatically from the measured waveforms. The measuring systems may be installed at substations of particular interest or where there is unusually high numbers of circuit breaker operations due to storms or other activity. In these cases the method makes use of normal switching operations and does not need special operations of circuit breakers to provide data.

Characteristics obtained by the method may be compared with characteristics measured by the manufacturer during type tests or with results of previous tests by this method to ascertain trends in circuit breaker performance.

The method may be used to:

1 Give an indication of deterioration of circuit breaker condition and to flag when maintenance is needed. This gives savings in allowing utilities to use condition-based maintenance practices rather than have to rely on traditional periodic maintenance.

2 Give an indication when the circuit breaker has reached the end of its technical and economic lifetime. Economic end of life occurs when expenditure on condition-based maintenance becomes excessive. Technical end of life may be demonstrated by comparing characteristics of circuit breakers measured by this method with similar characteristics measured during type tests.

In addition to providing information on circuit breaker condition the measurement method may also be utilised to give an indication of condition of the insulating systems in metal clad switchgear.

It will of course be realised that while the foregoing has been given by way of illustrative example of this invention, all such and other modifications and variations thereto as would be apparent to persons skilled in the art are deemed to fall within the broad scope and ambit of this invention as is herein set forth.

CLAIMS

1. A method of monitoring an AC circuit including the steps of:

providing a current transformer driven by a conductor of said AC circuit;

determining a capacitance between a component of said current transformer and said conductor;

utilizing said capacitance as the high voltage limb of capacitor voltage divider, the low voltage limb including a reference capacitance between the secondary winding of said current transformer and a reference potential, and

monitoring said circuit across said reference capacitance.

2. Apparatus for monitoring an AC circuit and including:

a current transformer adapted to be driven by a conductor of said AC circuit, whereby a capacitance is induced between a component of said current transformer and said conductor;

a reference capacitance between the secondary winding of said current transformer and a reference potential, and

signal output terminals across said reference capacitance.

3. Apparatus according to Claim 2, wherein the current transformer is selected from a measurement class transformer or a protection transformer in use in said AC circuit.

4. Apparatus according to any one of Claims 2 or 3, wherein the capacitance between said component of the current transformer and said conductor is used as the high voltage side of a voltage divider.

5. Apparatus according to Claim 4, wherein for unshielded current transformers the determined capacitance is the stray capacitance between the secondary winding of the current transformer and the conductor.

6. Apparatus according to any one of Claims 2 to 5, wherein the reference potential is ground.

7 Apparatus according to Claim 6, wherein the reference capacitor is a capacitor interposed in the ground link.

8. Apparatus according to Claim 7, wherein the reference capacitance is shortable by a removable link.

9. Apparatus according to any one of Claims 5 to 8, wherein the reference capacitance is in the region of $0.1\mu F$.

10. Apparatus according to Claim 4, wherein for shielded transformers, the capacitance is determined between the grounded electrostatic shield and the conductor.

11. A method accordingly to Claim 1, wherein said monitoring of the circuit is by monitoring means adapted to monitor the circuit in real time.

12. A method according to Claim 11, wherein the monitoring function is accompanied by a recording function for analysis against the known parameters of the circuit elements.

13. A method according to Claim 12, wherein the circuit element is a circuit breaker.

14. A method according to Claim 13, wherein data is obtained from both the supply and load sides of the breaker.

15. A method of monitoring a circuit breaker including:

providing the load and supply sides of said circuit breaker with monitoring apparatus each including a current transformer driven by respective load and supply conductors, each having a capacitance between a component of said current transformer and respective said conductors, each said capacitance forming the high voltage limb of capacitor voltage divider, the low voltage limb

including a reference capacitance between the secondary winding of said current transformer and a reference potential, and

monitoring said circuit breaker across both said reference capacitances.

16. A method according to Claim 15, wherein either current transformer is an integral part of the switchgear or is introduced into the switchgear.

17. A method according to any one of Claims15 or16, wherein for shielded transformers, said capacitance is that induced between the screen and the high voltage primary of the current transformer, and wherein said capacitance forms the high voltage limb of a voltage divider.

18. A method according to any one of Claims 15 to 17, wherein monitoring means performing said monitoring measures across one or more phases switched by the circuit breaker.

19. A method according to any one of Claims 15 to 18, wherein the voltage characteristics at the reference capacitors are measured during the opening and closing operations in a power system.

20. A method according to any one of Claims 1 and 11 to 19, wherein said monitoring is by recording apparatus selected from a digital oscilloscope or a PC-based transient recording system.

21. A method according to Claim 20, wherein said AC circuit includes a circuit breaker and wherein signals derived from the trip and close signals to the circuit breaker and signals derived from the secondary winding of at least one of the current transformers are fed to the recording apparatus.

22. A method according to Claim 21, wherein a Rogowski-coil-based current measuring device reads the signals from the secondary winding.

23. A method according to Claim 21, wherein the recording apparatus is triggered by a trip or a close signal to the circuit breaker, whereby the voltage and current waveforms associated with any opening or closing operation are recorded.

24. A method of determining the condition of the insulation of metal clad switchgear including:

identifying high frequency transient voltage waveforms superimposed on the supply voltage waveform, and

determining any correlation between said transient voltage waveforms and transient high frequency currents measured in the ground connection of the metal cladding.

25. A method according to Claim 24, wherein the identification of high frequency transient voltage waveforms superimposed on the supply voltage waveform is achieved by analysis of the output of monitoring apparatus including

a current transformer driven by a conductor of said metal clad switchgear, whereby a capacitance is induced between a component of said current transformer and said conductor which is utilized as the high voltage limb of a capacitor voltage divider, and a low voltage limb of said capacitor voltage divider comprising a reference capacitance between the secondary winding of the current transformer and a reference potential, wherein the output is the voltage waveform across the reference capacitance.

26. A method according to any one of Claims 24 or 25, wherein the transient current is measured using a Rogowski coil.

27. A method according to any one of Claims 24 to 26, wherein the current transformer is a measurement class transformer.

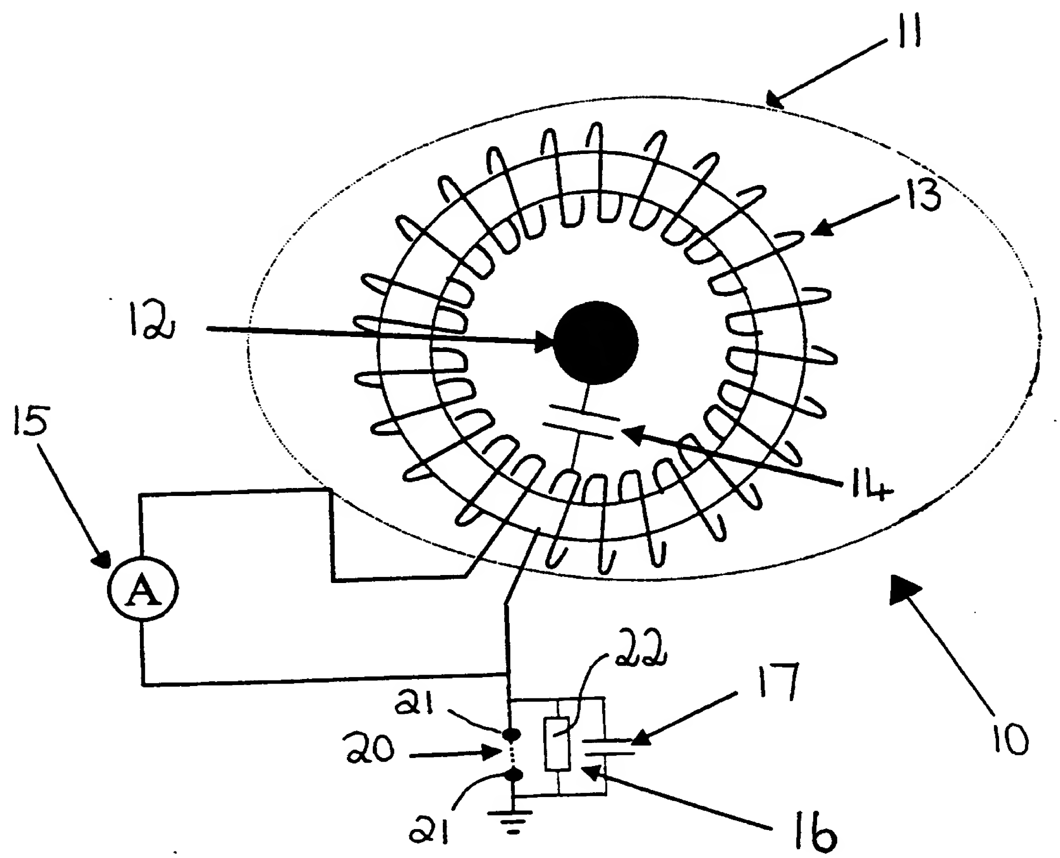


FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 99/00096

A.	CLASSIFICATION OF SUBJECT MATTER
Int Cl6:	G01R 19/00, 17/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC : G01R, H01H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT : (MONIT: OR TEST) AND (CURRENT TRANSFORMER) AND (CAPACIT:)
INTERNET : (MONIT: OR TEST) AND (CURRENT TRANSFORMER) AND (CAPACIT:)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	US 4689752 (FERNANDES R.A et al) 25 August 1987	
A	column 16 line 27 to line 59; figure 32	1,15
A	whole document	2-14, 16-27
	US 4794327 (FERNANDES R.A.)	
A	column 8 line 65 to column 10 line 13	1, 15
A	whole document	2-14, 16-27

☐ Further documents are listed in the continuation of Box C

☒ See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 March 1999	18 MAR 1999
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (02) 6285 3929	Authorized officer JAMES WILLIAMS Telephone No.: (02) 6283 2599

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU 99/00096

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4689752	CA	1251260	CA	1258098	CA	1258094
		CA	1258095	CA	1258096	CA	1258097
		EP	125050	EP	125796	EP	218220
		EP	218221	EP	218222	EP	218223
		EP	218224	EP	218225	JP	60043035
		JP	60046417	JP	63114536	JP	63114537
		JP	63121437	JP	63133844	US	4709338
		US	4709339	US	4758962	US	4777381
		US	4795973	US	4799005	US	4808917
		US	4829298	US	4855671	US	4714893
		US	4723220	US	4746241	US	4794328
		US	4796027	US	4794327	CA	1265844
		EP	181054	JP	61129580		
US	4794327	US	4709338	US	4758962	US	4777381
		US	4855671	CA	1251260	CA	1258098
		US	1258094	CA	1258095	CA	1258096
		CA	1258097	EP	125050	EP	125796
		EP	218220	EP	218221	EP	218222
		EP	218223	EP	218224	EP	218225
		JP	60043035	JP	60046417	JP	63114536
		JP	63114537	JP	63121437	JP	63133844
		US	4689752	UDS	4635055	US	4709339
		US	4795973	US	4799005	US	4808917
		US	4829298	US	4714893	US	4723220
		US	4746241	US	4794328	US	4796027
		US	4796027	CA	1265844	EP	181054
		JP	61129580				

END OF ANNEX